are considered, then

$$z_m = M + \frac{Z_d - M}{\sqrt{1-\left(\frac{\sqrt{2}x_m}{x_w} - \frac{1}{\sqrt{2}}\right)^2}} \quad . \tag{7}$$

The minimum value of z_m is the depth of the diffractor, Z_d .

Let T be the distance from the midpoint normalized by the half distance between wells:

$$T = \frac{x_m - \frac{x_w}{2}}{\frac{x_w}{2}} \quad . \quad (-1 < T < 1) \tag{8}$$

Now

$$z_m = M + \frac{Z_d - M}{\sqrt{1-\frac{T^2}{2}}} \quad , \tag{9}$$

where

$z_m = Z_d$ at $T = 0$ $\left(x_m = \frac{x_w}{2}\right)$ and

$z_m = M + \sqrt{2}(Z_d - M)$ at $T = \pm 1$ ($x_w = 0$ or x_w) .

For small T , z_m can be approximated by

$$z_m \approx Z_d + (Z_d - M)\cdot\frac{T^2}{4} \quad . \tag{10}$$

If z_m is normalized by Z_d , then

$$\frac{z_m}{Z_d} = \frac{M}{Z_d} + \frac{1 - M/Z_d}{\sqrt{1-\frac{T^2}{2}}} \quad \text{and} \tag{11}$$

$$\frac{z_m}{Z_d} \approx 1 + \left(1 - \frac{M}{Z_d}\right)\cdot\frac{T^2}{4} \quad . \tag{12}$$

If we call the variation of z_m with T z_{NMO} , then

$$z_{NMO} = z_m - Z_d = (Z_d - M)\cdot\frac{T^2}{4} \quad \text{and} \tag{13}$$

$$\frac{z_{NMO}}{Z_d} = \left(1 - \frac{M}{Z_d}\right)\cdot\frac{T^2}{4} \quad . \tag{14}$$

As shown Eq. (13) and Eq. (14), the moveout equation for a diffractor located at the center of wells in the mapped section can be described as a parabola with apex at $\left(\frac{x_w}{2}, Z_d\right)$ for small T . Also, the moveout decreases as M is close to Z_d for specific Z_d . The moveout as a function of M is smaller for small T and larger near the wells. Thus, the stacking process doesn't significantly affect the frequency content of the diffractions near the midpoint but stacking will tend to lowpass filter diffraction energy mapped near the wells. Fig. 1 shows moveouts in the mapped section computed using Eq. (11) and (12) where M is 0.77 Z_d . As shown the figure, Eq. (12) approximates well Eq. (11) for x_m within the distance $\frac{x_w}{4}$ from the midpoint $(|T| < 0.5)$.

Thus conventional post-stack migration for surface seismic data can be used to collapse the parabola from a diffractor (midway between the two wells) in the VSP-CDP mapped section by modifying the migration velocity. If Eq. (13) is converted to two-way traveltime, then

$$T_{NMO} = (Z_d - M)\cdot\frac{T^2}{4}\cdot\frac{2}{v_{diff}} \quad . \tag{15}$$

In a surface seismic geometry, the moveout for a diffractor at $(T = 0, Z_d)$ in a zero-offset section is

$$T_{NMO} = \frac{T^2 {x_w}^2}{4 Z_d v^*} \quad . \tag{16}$$

The velocity for post-stack migration used to collapse the curve from a diffractor in the VSP-CDP mapped section can be obtained by making Eq. (16) equal to Eq. (15):

$$v^* = \frac{{x_w}^2}{2Z_d(Z_d - M)}\cdot v_{diff} \quad . \tag{17}$$

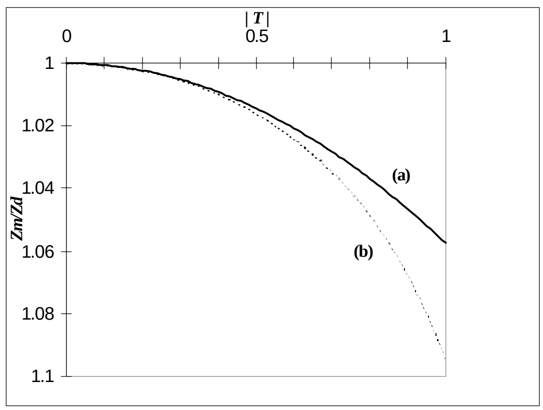

Fig. 1. Moveouts in the mapped section are derived
(a) by the approximate parabola equation (12)
(b) by the traveltime equation (11)
where M is 0.77 Z_d .

EXAMPLES

The above theory was applied to two velocity models. Synthetic seismograms for both models were made using a finite difference modeling method with the acoustic wave equation. The first model consisted of two reflectors and three diffractors between them (Fig. 2(b)). Each diffractor was located at a different position and a different depth. One was 100 ft from the source well, another was midway between the two wells, and the third was 100 ft from the receiver well. The distance between source well and receiver well was 400 ft. Sources and receivers were located between 1900 and 2900 ft. Both source and receiver intervals were 25 ft. The source was a zero-phase Ricker